EFFECT OF SPRAYS ON MITE AND INSECT SPECIES OF THE APPLE ORCHARD FLOOR

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Page 5, fourth paragraph, first line:

Coleoptera should read *Diptera*.

Also on page 5: Add the following to the section on SPECIES ENCOUNTERED

Coleoptera. Only the Coccinellidae were determined, and there were ten species, with *Hippodamia perplexa* most abundant.

THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION

NEW HAVEN

Contents

FOREWORD

The introduction of DDT provided apple growers with a highly effective insecticide for control of some destructive pests. In some cases, use of DDT was followed by outbreaks of mites. It was found that DDT killed the parasites and predators of mites, thus removing part of the natural control.

This discovery led to a re-examination of the effects of sprays on the fauna in orchards. Orchards are sprayed intensively and offer an excellent place to study this complex problem.

Dr. Philip Garman, the author of this Bulletin, is especially well qualified to investigate this relationship. He has wide experience both in studying beneficial insects and in controlling pests in orchards. Like many other investigations, this present one does not answer all the questions. The discussion on pages 13 to 15 summarizes the knowledge of the problem and some of the possibilities of practical application.

EFFECT OF SPRAYS ON MITE AND INSECT SPECIES OF THE APPLE ORCHARD FLOOR

Philip Garman

INTRODUCTION

Many people have considered the effect of sprays on the ecology of orchards. Pickett (21) and his associates (Lord, 14 and others) have studied the effect of pesticides extensively. Clancy (1) has added considerably to our knowledge. Smith (24) showed the effect of sulfur on predator mites of the grape, but all of these workers considered the effect of sprays on the fauna of the tree or vine rather than the ground underneath. More recently Hukusima (11, 12) considered some of the same effects in Japan.

All seem to be in agreement that sprays have a profound effect on the arthropods in an apple orchard. The exact causes, or the changes that occur when different insecticides are used, are not readily observed and require patience and study. Some of the data have been supplied by Sheals (23) and Klostermeyer and Rasmussen (13). Biology of the tree-inhabiting forms has been studied by Lord (14) and MacPhee and Sanford (15), and some of the factors involved have been supplied by Collyer (2, 3, 4).

The increase in abundance of the two-spotted mite, until recently only a minor pest, suggested the present study. The objective was to determine what changes from sprays applied to apple trees might be connected with this development.

During 1955 and 1956, Henry W. Hurlbutt studied mite populations in the sod under apple trees in sprayed, unsprayed, and lightly sprayed orchards. This work was presented to the University of Connecticut in 1957 as a master's thesis and part of it published (10).

In the studies reported here, arthropods were collected in four ways: (1) by sweeping uniformly grass and weeds under trees, (2) by clipping vegetation from square-yard areas and collecting the arthropods in Berlese funnels, (3) by sod collections of a definite volume, and (4) by examination of the bark on the trunks of apple trees.

During the first two years, no attempts were made to identify species, but in 1955 and 1956 determinations of mites were made, and in 1957 many other species were determined. Not all the 150 or 200 species have been determined, but the major groups have been separated and much information acquired regarding habits and life history of individual species.

SPECIES ENCOUNTERED

Of the various groups found in sweeping, Acarina belonging to the Tetranychidae and small flies (Diptera) predominated in 1957. In 1958, aphids and Diptera were predominant. Predators and parasites were in the minority as might be expected, and of these the spiders (Araneae) and dipterous parasites were more numerous than other groups. Secondary parasites were in the minority, but honeydew ants were collected in considerable number (1957), indicating an important ecological group dependent on the aphid.

In the bark collections, mites and springtails (Collembola) accounted for most of the specimens recovered, while among the predators, mites of the Mesostigmata and thrips (Thysanoptera) appeared to be the more numerous. Seven species of predator mites were collected in 1957 from the ground cover either by sweeping or extraction of grass clippings in Berlese funnels.

In the sod collections, by far the largest number of forms recovered were beetle mites (Oribatei), Mesostigmata, and Collembola. Of these only the Mesostigmata are known to have predatory instincts.

As a partial summary then, spiders, parasitic wasps, and Mesostigmata mites constituted the bulk of beneficial forms encountered in these investigations. Reduction of their numbers has been observed repeatedly following use of certain insecticides. The importance of this is probably connected in some way with the actual number of nonpredator and phytophagous species. In this regard there is a considerable difference between the fauna in the untreated checks and from the more powerful killing agents. The fauna after use of some insecticides is intermediate in numbers between the two extremes.

In all about 175 species have been identified* (see acknowledgments). The following paragraphs give a summary of the more important facts.

Acarina. Twenty-nine species of predaceous mites were determined, and three pest species. The Oribatei were present in large numbers but were not identified to species.

Araneae. The spiders were found in considerable numbers. Nineteen species were determined. The most abundant in 1957 were the Thomisidae (crab-spiders), Chebionidae, Salticidae (jumping spiders) and Oxyopidae in the order given. Dondale (6, 7) has reported on the significance of spiders in orchards and observed their feeding on Homoptera and some Lepidoptera. In Connecticut they have been seen feeding on leafhoppers, aphids, and mites. The smaller spiders accept mites readily in captivity. The total number of spiders reached a peak in July, and the population stayed fairly high until September. There were no peaks of abundance which would indicate generations.

Collembola were numerous in both sod and bark collections. They are probably important sources of food for predaceous forms. In 1957, the most numerous species were *Xenylla humida, Lepidocyrtes christienseni,* and *Onychivrus armatus.* Fifteen species were determined, and representatives of two families of *Symphyla.*

* A list of the species is available on application to the Department of Entomology, The Connecticut Agricultural Experiment Station.

Thysanoptera. Twenty species of thrips were identified, including four or possibly five predators. Thrips were especially abundant under bark scales where two-spotted mites hibernate. Three-fourths of the thrips there were predaceous, and *Haplothrips americanus* was by far the most abundant species. *Microcephalothryis abdominalis* was less abundant. In the grass *Anaphothrips obscurus,* a phytophagous species, was most abundant.

Hemiptera-Homoptera. The vast majority collected were *Cicadellidae* (leafhoppers), Cercopidae (spittle bugs), or Fulgoridae (plant hoppers). Both feed on plants, and *Polyamia inimicus* Say was numerous enough to provide a measure of the effects of sprays. The aphids *Aphis fabae* and *Myzus persicae* were abundant in some collections. The scale *Trionymus* (probably *americanus*) was also collected.

Hemiptera-Heteroptera. The predator species included *Amblyteles nasutus, Euchiatus variolaris, Nabis ferus,* and *Orious insidiosus.* The tarnished plant bug *Lygus lineolaris* was present.

Coleoptera. Small Diptera in the families Agromyzidae, Ephydridae, and Chloropidae were very abundant. Only Syrphidae were identified. *Toxomerus (Mesogramma) marginatus* was abundant, and three other species were identified. The larvae of many Syrphids feed on aphids or other insects. There were also a few Asilidae and an occasional Tachinid.

Hymenoptera. About half of the Hymenoptera collected were either parasites or fed on aphid honeydew. The rest were apparently parasites of Lepidoptera or Diptera. The most abundant species were representatives of *Aphidius, Cinetus, Platygaster,* and *Tetrastichus.*

Lepidoptera. Few were collected and no identifications were attempted.

Neuroptera. The only species of this group was *Chrysopa occulata,* which feeds on aphids.

SPRAYS

The examination of fauna was made under trees sprayed either experimentally or by growers with eight to ten applications. In all cases the sprays were chosen as being potentially effective in control of all apple pests. However, ryania was used in one test specifically because of favorable reports of its effects on parasites and predators.

The effects of sprays on thrips and mites in bark are given in Table 1. There were more clover mites (Bryobia) on trees sprayed with DDT-parathion or malathion-ryania-captan combinations. When thrips were very abundant, two-spotted mites were scarce. These mites were most abundant following treatment with methoxychlor-captan or methoxychlor-malathion-captan.

EXPERIMENTS

The first year, examination of the ground cover fauna showed the following differences: (1) Leafhoppers became abundant under lead arsenate sprays, (2) aphids were eliminated by four combination sprays, and (3) all Coleoptera disappeared following methoxychlor-DDD and Dilan-DDD sprays.

TABLE 1. Comparison of bark fauna in 1954 and 1955 collections

1954		1955	
Thrips		*Thrips*	
Scarce.	Methoxychlor-DDD-Captan-glyodin	*Scarce.*	1. Methoxychlor-Captan 2. DDT-parathion-Captan-glyodin 3. Ryania-Captan-glyodin 4. Lead arsenate-dieldrin-Captan
Abundant.	1. Unsprayed 2. Lead arsenate-Captan-malathion 3. Methoxychlor-DDD-Captan-glyodin	*Abundant.*	1. Unsprayed 2. Lead arsenate-Captan
Mesostigmata		*Mesostigmata*	
Scarce.	All except checks	*Scarce.*	Methoxychlor-Captan
Abundant.	Unsprayed	*Abundant.*	1. Unsprayed 2. Ryania-Captan-glyodin 3. Diazinon-Captan-glyodin
Oribatei		*Oribatei*	
Scarce.	All treatments	*Scarce.*	1. Lead arsenate-Captan 2. Ryania-Captan-glyodin 3. DDT-parathion-Captan-glyodin
		Abundant to Moderate.	1. Methoxychlor-malathion 2. Methoxychlor-Captan
Bryobia		*Bryobia*	
Scarce.	Unsprayed	*Scarce.*	1. Unsprayed 2. Ryania-Captan-glyodin
Abundant.	All others	*Abundant.*	All others

Repeated the following year, we noted abundance of Syrphidae with captan-methoxychlor-glyodin spray and methoxychlor-TDE-malathion-captan sprays, but scarcity under unsprayed checks. *Stethorus punctum* (mite predator) was present in all treatments but not in the unsprayed. *Bryobia praetiosa* (clover mite) was also present with all treatments but not in the unsprayed. This was attributed to abundance of predator mites in the sod under checks. It could not obviously be attributed to effect of spray on *Stethorus* which were more abundant under sprayed trees. Sweepings began to show differences, however, in Syrphidae and parasitic Hymenoptera under Ryania-glyodin treatments. The most toxic material to beneficial forms in these experiments appeared to be parathion. Observations on thrips, Mesostigmata mites, and others indicated the same trend.

Repeated the third year, experiments showed the same general effects. It was noted that *Bryobia praetiosa* (clover mite) and *Tetranychus telarius* (two-spotted mite) were less abundant in unsprayed orchard ground cover. DDT-parathion reduced Bryobia, but there was also a reduction in the number of predator mites in heavily sprayed orchards.

Still more extensive collections during the last two years seemed to show the same general trends. Collections at about two-week intervals throughout the season were totalled and indicated that we were getting general reduction of all forms from mixtures containing DDT-parathion or methoxychlor-malathion. In view of this, attempts were made to establish ratios between plant feeders or between plant feeders plus scavengers and predators plus parasites by dividing the first group by the last:

$$\frac{\text{scavengers plus plant feeders}}{\text{parasites plus predators}}$$

Sod collections continued to show a low count of Mesostigmata in all collections from sprayed plots. An attempt was made here to establish ratios between different groups of mites with a view to determining feeding habits. Also included was an attempt to connect predatory mites with small insects such as Collembola (springtails). A summary of these data is given in Table 2.

TABLE 2. Sod collections, 1957: Percentages of different groups recovered

Treatment	Mesostigmata	Oribatei	Collembola	Homoptera
Lead arsenate-malathion-captan	2.5	51.6	4.2	18.3
Guthion-captan	2.4	77.2	1.6	17.8
Guthion-thiram	.3	62.6	4.1	31.7
Ethion-captan	1.8	65.4	8.7	18.6
Ethion-thiram	10.2	62.4	2.3	21.2
Ryania-lead arsenate-captan	6.5	22.7	4.5	63.2
Ryania-captan	3.2	53.2	4.0	38.2
Check (under unsprayed tree)	15.3	36.6	30.6	4.7
Check – meadow	13.6	43.5	21.3	13.6

Bark and ground cover collections (1957, 1958) were about the same as in previous years (1954, 1955). Sweepings were made at regular intervals from plots with dense orchard grass and miscellaneous weeds. More insects were collected under unsprayed trees and those sprayed with lead arsenate-thiram, and fewer under DDT-parathion-captan (as might have been predicted from previous results), Table 3.

In sprayed orchards the proportion of beneficial forms was low until July, but increased rapidly with certain treatments after that. One of the outstanding observations concerns the rapid increase of Hymenopterous parasites in plots heavily infested with aphids. Early in the season ryania-lead arsenate-captan gave the most favorable ratio, as seen in Table 4. In August, due to an increase of Hymenoptera parasites there was only slight difference between Kepone-captan and ryania-lead arsenate-captan from the ratio standpoint. Kepone provided very little protection from tree-infesting aphids early in the season, but there was a drastic reduction in their numbers after the August 15 collections. As seen in Table 4 there appears to be a gradual improvement in the ratios from early to late season. Comparisons of Guthion-captan with standard insecticide-fungicide treatments including chlorin-

TABLE 3. Ratio of harmful to beneficial insects, percentage Hymenoptera Parasitica in the collections and total insects and mites

Treatment	Ratio*	Hymen. Par. per cent	Total insects and mites
Ryania-lead arsenate-captan	3.3	15.4	318
Kepone-captan	4.7	15.7	440
Lead arsenate-malathion-captan	5.5	12.4	210
Delnav-captan	7.2	8.9	237
Sevin-Kelthane-captan	8.2	6.2	194
Guthion-captan	9.3	7.8	154
Methoxychlor-glyodin-ferbam	11.8	6.9	848

* High ratios are considered less desirable.

TABLE 4. Changes in the ratios of harmful to beneficial forms between July 1 and August 13, 1958

Treatment	Date	Ratio
Kepone-captan	July 1	14.7
	July 16	8.0
	July 30	8.6
	August 13	6.6
Sevin-captan-Kelthane	July 1	18.4
	July 16	12.6
	July 30	14.3
	August 13	8.2
Lead arsenate-ryania-captan	July 1	6.0
	July 16	6.2
	July 30	3.1
	August 14	8.5
Control—no spray	July 1	4.7
	July 16	6.3
	July 30	3.1
	August 14	8.5

TABLE 5. Ratios from ground sweeps in orchards receiving Guthion and regular sprays including chlorinated hydrocarbons, July 1958

Orchard	Guthion	Chlorinated hydrocarbons, etc.
Avalon Farms, Bantam	9.0*	59.0
Josephy, Bethel	2.6	19.4
Dodd, Woodbridge	5.5	5.8
Experiment Station Farm, Mt. Carmel	9.6	17.0

* Average of two collections. Presumably phytophagous forms divided by predators plus parasites.

ated hydrocarbons such as dieldrin, DDT, or methoxychlor revealed that the ratios were much more favorable where the Guthion was used. The same results appeared in four widely separated commercial orchards (Table 5). In several of these comparisons aphids were more abundant following chlorinated hydrocarbon sprays with malathion, and in general there were more insects.

EFFECTS OF SPRAYS ON INSECTS AND MITES

Aphids and Their Enemies

Work in 1957 provided useful information on the overall effect of certain sprays because of considerable numbers of aphids in the grasses beneath the trees. It showed the relative harmlessness of ryania as compared with methoxychlor-DDD. The figures also show a relatively mild effect for lead arsenate. Following this an attempt was made to show the effect of sprays on the genus Aphidius, an important aphid parasite (Table 6). Except for lead arsenate-thiram, the same relation held here as for lady beetles.

Continuing and combining several treatments and two different counts, there appeared to be a connection between the total parasite-predator complex (Table 7) and the aphids on the trees the following spring. Inasmuch as the species on the trees involved mostly the grain aphis (*Aphis avenae*), it may be assumed that reduction in numbers may be associated in some way with the parasite-predator populations in the ground cover. So, in spite of the small number of aphids collected under DDT-parathion trees during the summer of 1957, the population the following spring (Table 7) was no less than occurred on unsprayed trees. The high lady beetle level for both thiram treatments is interesting both from the standpoint of aphids collected and the bud count in 1958.

TABLE 6. Effect of sprays on Coccinellidae (lady-beetles) and Aphidius (aphid parasites), 120 sweeps on August 15

Treatment	Number collected	
	Coccinellidae	Aphidius
DDT-parathion (Bl. Leaf 253)	6	1
Methoxychlor-malathion-captan	5	2
Ryania-captan	8	2
Ryania-thiram	9	6
Lead arsenate-captan	22	10
Lead arsenate-thiram	29	1
Check — unsprayed	46	12

Mites and Their Enemies

The number of thrips under bark showed a trend opposite to the number of mites recovered (Table 8) in 1956. Some of the thrips in these collections were plant feeders, but the majority were predators.

Sod collections produced many predator Mesostigmata which were high for ryania-captan and low for EPN-dieldrin-captan. Examination of

Table 7. Relations between the predator-parasite complex in the ground cover and aphid abundance in the following year in the trees, 1957

Aphidius and lady beetles	Eggs per 20 8 inch twigs March, 1958	Aphids per 20 buds April, 1958
58	67	34
31*	48	59
10*	108	68

* Averages of several treatments, 9 collections.

Table 8. Relation between number of thrips and two-spotted mites under bark

Treatment	Number of thrips*	Number of T. telarius
Lead arsenate-captan	136	48
Ryania-malathion-captan	48	132
EPN-(dieldrin early)-captan	6	448
Methoxychlor-captan	0	1548

* Mostly predators. Bark scrapings for a distance of 18 inches from ground.

Table 9. *Tetranychus telarius* and *Bryobia praetiosa* collected under trees with different sprays, and the ratio of non-predators to predators and parasites

Treatment	Number*	Ratio†
Check – unsprayed	72	5.7
Ryania-captan	209	8.2
Ryania-thiram	272	11.0
DDT-parathion-captan	303	11.9
Methoxychlor-malathion-captan	552	12.9
Lead arsenate-captan	651	11.6
Lead arsenate-thiram	1749	15.5

* Nine collections at two-week intervals.
† Non-predators or parasites to predators and parasites.

unsprayed, lightly sprayed, and heavily sprayed orchards showed a similar trend. Ratios between different forms were calculated and are given in Table 9. These data combined with total recoveries of predators are an indication that populations of two-spotted mites are being reduced by predators. The ratios correspond reasonably well with *T. telarius* in sweepings, and there is a tendency for that species to reach outbreak proportions wherever ratios are high in late summer.

None of these data provide the complete answer regarding predator feeding habits, but they do show a definite trend for these mites to build up in the ground cover with certain spray programs. In these tests, the fewest mites were obtained under lead arsenate-captan and ryania-captan sprayed trees and most under lead arsenate-thiram and methoxychlor-malathion-captan. Combinations with diazinon were similar to lead arsenate-thiram and methoxychlor-malathion-captan. This indicates that methoxychlor and diazinon are important factors in the build-up of two-spotted mites in the ground cover from whence they may and often do migrate into the trees and damage the foliage.

Thus, during the period under consideration, it was noticed that two-spotted mites also tended to become abundant in trees sprayed with chlorinated hydrocarbons such as methoxychlor, whereas the European red mite became abundant generally where lead arsenate was the insecticide. The fact that the fungicide sometimes changes the picture is evident on comparing thiram and captan (Table 9).

We see, therefore, a decrease in mite abundance under bark following a rise in thrips; a decrease of predator species following certain sprays; a rather profound change in the ratios in ground cover collections with some insecticides but not others; and finally a rise where the ratios between mites and predators are highest.

Leafhoppers

While no attempt has been made to study predator-parasite relations of leafhoppers, their population under sprayed trees is interesting in showing (Table 10) a nearly complete reversal of the trend for aphids and mites. These figures would indicate that outbreaks of leafhoppers may be expected when lead arsenate or ryania is the only insecticide. Outbreaks are well known to have occurred in the past with lead arsenate schedules.

It is apparent both from the 1957 and 1958 collections that the percentage of leafhoppers is nearly always greater under unsprayed than under trees sprayed with modern insecticides.

Parasites and Predators

Table 11 and 12 give the numbers and percentages of spiders recovered from ground sweeps. Apparently, in this experiment more individuals were captured under trees sprayed with ryania than any other insecticide. On the other hand, lead arsenate has apparently reduced spiders in contrast with its mild action on hymenopterous parasites as shown in Table 12. When we combine all parasites and predators as in Table 12, there are increased numbers in both lead arsenate and ryania as compared with DDT-parathion or methoxychlor-malathion. If, then, as in 1957 the total insects and mites are calculated and divided by the number of recognized parasite-predators (Table 12) we see a relatively low figure for ryania and a high figure for lead arsenate-thiram with others in between. A somewhat surprising and baffling relation exists here between the ratios and the numbers of Bryobia and Tetranychus captured with the methods employed.

Another phenomenon observed is the rather high ratios generally early in the season and sometimes late in the season with a relatively low ratio in midsummer. This can only mean that beneficial forms are much more numerous in mid-season than at either end. It also suggests

TABLE 10. Effect of sprays on the ground cover population of leafhoppers, 1957

Treatment	Numbers* Collected
DDT-parathion-captan	3
Methoxychlor-malathion-captan	9
Lead arsenate-thiram (Thylate)	13
Ryania-thiram (Thylate)	15
Lead arsenate-captan	35
Ryania-captan	36
Check	144

* Based on one species, **Polyamia inimicus**, found in large numbers in grass under the trees. Totals from 9 collections at two-week intervals.

TABLE 11. Effect of sprays on spiders in sweepings, 1957 (total spiders as per cent of the arthropods collected)

Treatment	Number collected	Per cent
DDT-parathion-captan	19	2.5
Lead arsenate-captan or thiram*	39	1.2
Methoxychlor-malathion-captan	44	2.7
Ryania-captan or thiram*	85	2.5
Check – unsprayed	86	3.2

* Averages of two separate treatments. Nine collections for all treatments.

TABLE 12. Effect of sprays on Hymenoptera and parasites and predators.

Treatment	Hymenoptera	Parasites and Predators	Ratio Harmful/Beneficial
Check – unsprayed	236	482	5.7
Lead arsenate-thiram	104	220	15.5
Lead arsenate-captan	99	232	11.6
Ryania-captan	80	199	8.2
Ryania-thiram	71	209	11.0
Methoxychlor-malathion-captan	48	113	12.9
DDT-parathion-captan	23	93	11.9

a change in the mid-season programs of sprays to take advantage of the change.

Four new materials were used in 1957 and 1958. The effect of these on the fauna may be summarized as follows:

(1) Guthion-Captan 1957-1958

1. Little effect on spiders, little or no reduction of parasitic Hymenoptera.
2. Reduction of total insects including plant feeders; moderate ratio.
3. Reduced aphids and leafhoppers.
4. Resulted in a low population of two-spotted mites and European red mite.

(2) Sevin-Captan-Kelthane 1958

1. No effect on spiders.
2. No reduction in total insects and a fairly high ratio plant feeders, etc. to others.
3. Reduced aphids and leafhoppers.
4. No two-spotted or European red mites.

(3) Kepone-Captan 1958

1. Increase in parasitic wasps toward end of season.
2. Increase in total insects with good ratio late in season; poor early.
3. Increase in aphids, but not leafhoppers.
4. No two spotted mites or European red mites in cover; outbreak of European red mites in late August.

(4) Delnav-Captan 1958

1. Some reduction of spiders and parasitic Hymenoptera.
2. No increase in total insects and a moderate ratio.
3. Reduction of aphids and leafhoppers.
4. No outbreaks of two-spotted mites in ground cover or European red mites on trees.

FUNGICIDES

The sprays used in many of these tests allowed a comparison of the effects of captan and thiram. Results in 1957 were not entirely confirmed in 1958. The differences which did occur indicated that thiram was somewhat more toxic to beneficial insects than captan.

DISCUSSION

From these studies it is apparent that bark, sod, and ground cover fauna are greatly reduced by some sprays and not by others. There is also a selective action within the combination range of the orchard insecticides and fungicides used. An insecticide with one fungicide, for example, may be relatively harmless to predator and parasite while with another the combination may be destructive.

Complete elimination of sprays works well in Connecticut for some pests but not others. Apparently the major pests in this area may either have protective habits or devices against their foes or they may not have too many important ones anyway.

From general observations throughout the State it appears that two-spotted mites, which usually start in the ground cover, are much less troublesome where lead arsenate is the only insecticide, much more troublesome where methoxychlor is substituted.

Increase of mites frequently follows nitrogen fertilization. This introduces another factor since some of the insecticides and fungicides now used contain nitrogen. However, in plots fertilized with the same nitrogenous fertilizer each year there has been a marked difference between those sprayed with lead arsenate and the usual chlorinated hydrocarbons. The European red mite has been most troublesome in the lead arsenate plots, the two-spotted mite in those sprayed with chlorinated hydrocarbons.

It is evident that ryania and lead arsenate among the insecticides are least destructive to natural enemy or beneficial insect complexes. Next in line and very little different is Kepone. The most destructive of all the insecticide combinations were DDT-parathion and methoxychlor-malathion, the latter appearing worse in its action on predator mites. Among the fungicides, thiram appeared to be more destructive to beneficial forms than captan, but on the other hand destroyed more leafhoppers than captan, indicating some beneficial action.

In the soil studies, more predator mites (Mesostigmata) were found with ryania-captan than any other treatment. There was considerable reduction here with all others especially any containing methoxychlor. While it is impossible to judge accurately from data collected so far, it appears that the phosphates Guthion and Nialate (Ethion) gave some reduction of soil Mesostigmata (Table 2). Results in 1958 indicate that in the ground cover at least, Guthion and Delnav, for example, are no worse than lead arsenate-malathion-captan because of the phosphate present in that mix.

The general action of insecticides on Mesostigmata and the lack of action of lead arsenate has been confirmed by Hurlbutt's work in several orchards in Connecticut (10).

As to bark collections, the same general picture prevails. In this case, predator thrips have been much less abundant where treatments containing methoxychlor or DDT-parathion or other phosphates have been used than with ryania or lead arsenate.

To give minimum reduction of beneficial forms the field, then, narrows down to lead arsenate, ryania, and possibly Kepone and captan. What are the possibilities of using these materials in a satisfactory spray program in Connecticut?

One must consider that leafhoppers and aphids as well as the European red mite will develop with a pure lead arsenate-captan program. To combat them additives of one sort or another are needed, any of which may increase destruction of mite predators. Malathion as already mentioned gives a moderately high ratio, ryania-lead arsenate a much better one. Of the phosphate-captan combinations all are better than methoxychlor, but not quite as good as ryania-lead arsenate. The real test of the matter lies in the degree of clean fruit obtained and lack of leaf or fruit injury since most of the chemicals that are easy on predator-parasite populations lack control of such insects as leafhoppers, mites or aphids, and some lack control of such important insects as the plum curculio. Some also cause leaf or fruit injury.

If we start looking for selective insecticides for each pest or group, we find ourselves with one for curculio, one for apple maggot, one for codling moth, and so on. (In this connection see Hagen and Smith, 9, p. 90.) A good answer would seem to be to look for one chemical or combination which depresses all forms equally (recently termed wide-spectrum insecticides) and not differentially as appeared to be the case for many chemicals in these investigations.

Complete or effective survival of all predators and parasites would be just as difficult or more difficult to attain than universal depression of pests and their enemies. It has been said that whenever uniform depression of both pests and their enemies occurs, the form with the highest reproductive capacity comes back first, and it may then go on

to become really destructive. But, not all the primary pests have high reproductive potentials, so it would necessitate use of chemicals that would depress these with low potential uniformly (with their enemies) and the high potential ones selectively.

Two groups in question here are mites and aphids. Enemies of these have been shown to return quickly after spraying stops, so the problem becomes either (1) use of a systemic which does not affect enemies, or (2) a quick acting, quick disappearing pesticide. Unfortunately development of resistance must also be considered. Another approach would, as already mentioned, be to lower the reproductive potential, say of the worst pests, by cultural and nutritive controls, or by bringing in natural enemies, including disease. Utilization of a balanced fertilizer helps, or avoidance of one overloaded with nitrogen.

SUMMARY AND CONCLUSIONS

Orchard sprays are definitely affecting the fauna of sod and ground cover as well as that hibernating under bark scales of the lower trunk.

Destruction of beneficial forms seems to be in some way connected with rise of two-spotted mites. Predators such as spiders (Araneae), Coccinellidae, Anthacoridae, Neuroptera, and parasitic Hymenoptera are reduced by some sprays but not others.

The best sprays so far seem to be those that allow a moderate ratio of harmful to beneficial insects and mites, and have at the same time a fairly wide range of insect toxicity. Guthion-captan, Sevin-Kelthane-captan, and Kepone-captan are promising. All have limitations.

About 175 species of insects and mites have been identified or partly identified in these studies. It is estimated that at least 200 or more occur in the orchards studied.

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